

Research Article

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Study of dynamics of electro-chemical properties of submerged soils

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Summary

Wetland rice systems in Asia make a major contribution to global rice supply. The system is also able to maintain soil fertility on a sustainable basis. The essential components of wetland rice culture comprise cultivation of land in the flooding, puddling and transplanting of rice seedlings into puddled rice paddies, and growing the rice crop under flooding. The wetland rice system, growing rice in submerged soils has a great ameliorative effect on chemical fertility: largely by bringing pH in the neutral range, resulting in better availability of plant nutrients and accumulation of organic matter. Submergence bring a lot changes in redox potential which in turn gives the idea of reduction of nutrients to release to soil solution to make available to plant. This article revealed the dynamic changes of soil pH, electrical conductivity and Redox potential on submergence.

Key words : Flooding, Submergence, Soil pH, Electrical conductivity, Redox potential

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Introduction

Global estimation of wetland area range from 700 to 1000 M ha (Kirk, 2004). The success of rice as a food crop stems from its origins as a wetland plant and its ability to withstand soil submergence with the attendant improvements in water and nutrient supplies. A corollary is that rice is more sensitive to water deficiency than most other crops, and the critical factors in its productivity are the supply of water to the soil, from rain, river, reservoir or groundwater, and the ability of the soil to retain water. Hence, most rice is produced and the highest yields attained on the alluvial deposits associated with major rivers and their deltas.

More than 90 per cent of the production is in Asia, distributed unevenly over four rice 'ecosystems'

distinguished by land and water characteristics and adaptations of the rice plant to them. In Asia, India stands first with an area of 42 M ha followed by china 32 M ha of cultivation followed by countries like Indonesia, Bangladesh and Vietnam stands in area of rice ecosystem.

Wetland rice systems in Asia make a major contribution to global rice supply. The system is also able to maintain soil fertility on a sustainable basis. The essential components of wetland rice culture comprise cultivation of land in the wet or flooded state (puddling), transplanting of rice seedlings into puddled rice paddies, and growing the rice crop under flooding. The land is dry or flood fallowed during the turnaround period between two crops. However, in the present context of increasing freshwater scarcity, there is a case to shift

from the traditional way of growing rice to ways that are water-wise. In this context, it is crucial that the benefits of the wetland rice system on soil fertility and productivity are considered.

This article examines the benefits of growing rice in flooded conditions on soil fertility and its maintenance. Several research has shown that the wetland rice system (growing rice in submerged soils) has a great ameliorative effect on chemical fertility: largely by bringing pH in the neutral range, resulting in better availability of plant nutrients and accumulation of organic matter. In order to examine the changes and benefits of growing rice using submerged conditions, this experiment has been conducted to study the dynamics of electrochemical properties of submerged soils.

Resource and Research Methods

The experiment was conducted during *Kharif* 2016 at Department of Soil Science and Agricultural Chemistry, GKVK, Bangalore (Karnataka) 12°58'N latitude and 77°35'E longitude at an altitude of 930 m above mean sea level (MSL). The relative humidity ranged from 90.0 to 45.0 per cent during the crop period. Four treatments were replicated four times in Randomized Blocks Design to observe the change in electro-chemical properties on submergence. The four treatments imposed were control (T_1), only urea

application (T_2), neem coated urea (T_3) and mud coated urea (T_4). Initially during the first sampling soil was not submerged we have taken the samples in dry soils and soil submerged for the two weeks without crop. After second observation, we have transplanted the crop and observed the electrochemical changes in the soil. The third and subsequent observations were made after submergence with standing crop. Nitrogen and potash were applied in four equal splits (25% each at basal, active tillering, panicle initiation and flowering). Entire dose of phosphorus was applied basally. Neem coated urea is a urea coated with natural neem oil or neem products which inhibits the nitrification early and also improves the nitrogen use efficiency. Whereas mud coated urea is coating of urea with locally available mud and dried so as to controlled release of urea.

Soil pH and redox potentials were measured using pH meter at room temperature with ratio of soil to water is 1:2.5. The weight of water along with soil while sampling also taken to counted to bring and add required water to soil to attain the ratio of 1:2.5. The same sample used to study the electrical conductivity by conductivity meter.

Research Findings and Discussion

The chemistry of submerged soils is a subject of unusual scientific and ecological interest. Flooding of dry

Table 1: Electro-chemical properties of submerged soils from day of submergence to fifteen weeks

Particulars	pH				EC (dS m ⁻¹)				Eh (mV)			
	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄
Initial	5.63	5.67	5.78	5.61	0.12	0.13	0.12	0.12	6.79	6.87	7.48	7.10
1 week	5.91	5.95	6.07	5.89	0.14	0.15	0.14	0.14	5.52	5.58	6.09	5.77
2 week	6.30	6.31	6.28	6.30	0.17	0.18	0.17	0.17	4.49	4.54	4.95	4.69
3 week	6.35	6.32	6.33	6.26	0.28	0.31	0.33	0.35	3.65	3.69	4.02	3.81
4 week	6.41	6.45	6.58	6.39	0.57	0.59	0.62	0.67	2.27	2.30	2.51	2.38
5 week	6.71	6.70	6.72	6.68	0.70	0.71	0.73	0.79	1.78	1.80	1.96	1.86
6 week	6.69	6.69	6.72	6.67	0.95	0.96	0.99	1.08	-21.46	-21.70	-23.65	-22.42
7 week	6.74	6.78	6.92	6.71	1.02	1.02	1.05	1.15	-41.24	-41.70	-45.45	-43.09
8 week	6.96	6.70	6.95	6.85	1.08	1.09	1.12	1.22	-61.02	-61.70	-67.25	-63.75
9 week	7.10	6.84	7.09	6.99	0.90	0.91	0.93	1.01	-73.53	-74.35	-81.04	-76.82
10 week	7.23	6.97	7.22	7.12	0.84	0.85	0.87	0.95	-87.13	-88.10	-96.03	-91.03
11 week	7.36	7.10	7.35	7.25	0.79	0.80	0.82	0.90	-103.25	-104.40	-113.80	-107.88
12 week	7.29	7.26	7.11	7.16	0.75	0.75	0.77	0.84	-122.36	-123.72	-134.85	-127.83
13 week	7.10	7.18	7.38	7.26	0.43	0.48	0.52	0.54	-144.99	-146.60	-159.80	-151.48
14 week	6.90	7.14	7.30	7.12	0.23	0.26	0.28	0.29	-171.81	-173.73	-189.36	-179.51
15 week	6.80	7.02	7.03	7.10	0.22	0.25	0.27	0.28	-203.60	-205.86	-224.39	-212.71

soil cuts off its oxygen supply, aerobic micro-organisms use up the trapped oxygen and become quiescent or die, then anaerobic micro-organisms use oxygen-rich soil components in their respiration and set in motion a series of electro-chemical, chemical and biological changes that profoundly affect the quality of the soil (Ponnamperuma, 1977).

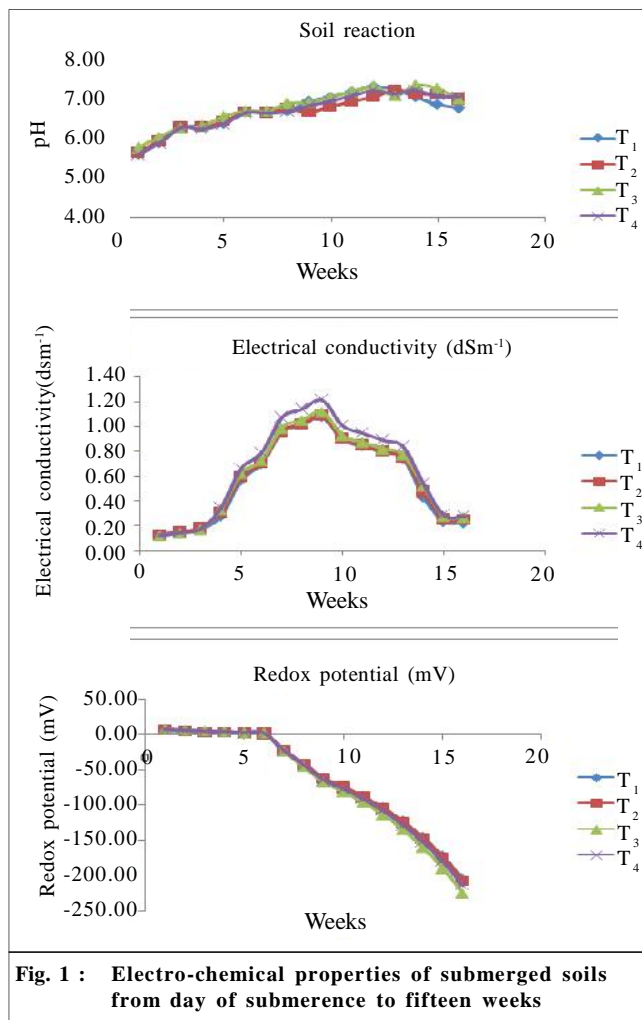
Soil reaction :

The pH values of submerged soils measured in air-free aqueous suspensions are slightly higher than those of the corresponding soil solutions (Ponnamperuma *et al.*, 1972). This may be due to the inversion of the suspension effect by the divalent cations Ca^{2+} , Fe^{2+} , and Mn^{2+} (Raupach, 1954) and to dilution and loss of CO_2 during measurement of the pH of the soil suspension (Ponnamperuma, 1972). Because the soil solution is the thermodynamically meaningful phase and the pH of a solution can be measured with the minimum of the liquid junction potential and CO_2 errors.

The current study has been conducted in slight acidic soils and pH ranges from 5.6 to 5.8. After submergence, the significant increase in the pH was observed in the all treatments. Here, the pH has increased drastically after submergence and once it has attained the constant after fifth week to an pH of 6.7 to 7.2 (Table 1). After the crop has attained the hard dough stage, irrigation has stopped and the soil became dry, hence, the decrease in the pH has noticed. The increase in pH is due to the production of ferrous and manganous hydroxides. When a rice soil dries these compounds take up oxygen and are converted to the insoluble oxidized forms. So, the changes due to submergence have clearly graphed in the Fig. 1.

Redox potential :

The single electro-chemical property that serves to distinguish a submerged soil from a well-drained soil is its redox potential. The low potentials (0.2 to -0.4 V) of submerged soils and sediments reflect this reduced state, the high potentials (0.8 to 0.3 V) of aerobic media, their oxidized condition. When an aerobic soil is submerged, its Eh decreases during the first few days and reaches a minimum; then it increases, attains a maximum, and decreases again asymptotically to a value characteristic of the soil, after 8-12 weeks of submergence (Yamane and Sato, 1968). The course, rate and magnitude of the Eh decrease depend on the kind and amount of organic



matter, the nature and content of electron acceptors, temperature and the duration of submergence.

In the present study, the redox potential ranged from 7.48 to -224.39 mV as shown in Table 1. This is due to the submergence, subsequently the reduction of organic matter and reducible species. According to Sahrawat (2005), submerging aerobic soils in water decreases its Eh that drops and stabilizes at a fairly stable range of +200 mV to -300 mV depending on the soil, especially the content of organic matter and reducible species (nitrate, sulphate and ferric iron), particularly iron. The Eh of soils controls the stability of various oxidized components [oxygen, nitrate, manganese (Mn IV), ferric (Fe III) iron, sulphate (SO_4^{2-}) and carbon dioxide] in submerged soils and sediments.

Electrical conductivity :

According to Ponnamperuma (1972), the specific

conductance of the solutions of most soils increases after submergence, attains a maximum and declines to a fairly stable value, which varies with the soil. The changes in conductance reflect the balance between reactions that produce ions and those that inactivate them or replace them with slower moving ions. The increase in conductance during the first few weeks of flooding is due to the release of Fe^{2+} and Mn^{2+} from the insoluble Fe (III) and Mn (IV) oxide hydrates, the accumulation of NH_4^+ , HCO_3^- and RCOO^- in acid soils. The present investigation has also give the same trend of the reviewers as shown in the Fig. 1. The electrical conductivity of initial soils is 0.12 dS m^{-1} and the maximum of 1.08 to 1.22 dS m^{-1} in the eighth week of submergence (Table 1). Electrical conductivity decreased gradually after thirteen weeks of submergence to 0.4 dS m^{-1} in all treatments as shown in Fig. 1. Later it has attained the static value after the soil dried for seed dough stage.

Conclusion :

Submergence of a slight acidic soil changes its electro-chemical properties like soil reaction, electrical conductivity and redox potential. Soil pH drastically increased after submergence and attained the pH of 6.7 to 7.2 after fifth week of submergence. After the crop has attained the hard dough stage, irrigation has been stopped and the soil became dry, hence, the decrease in the pH was noticed. The redox potential ranged from

7.48 to -224.39 mV. The specific conductance of the solutions of most soils increases after submergence, attains a maximum and declines to a fairly stable value, which varies with the soil. This is due to the submergence, subsequently the reduction of organic matter and reducible species. There is no significant difference among the treatments but a considerable change has been observed in all treatments in their properties of electro-chemical properties on submergence.

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